Technical Report 1902
June 2003

Coastal Contaminant Migration Monitoring: The Trident Probe and UltraSeep System

Hardware Description, Protocols, and Procedures

SSC San Diego

Computer Sciences Corporation

Naval Facilities Engineering
Services Center

Cornell University/Suffolk
County Health Services

Cornell Cooperative Extension
of Suffolk County

SSC San Diego
San Diego, CA 92152-5001

Executive Summary

Coastal landfills and hazardous waste sites pose a potential environmental threat to surface water bodies through the exchange of groundwater-borne contaminants. Because of this potential threat, there is a general requirement to determine if contaminants from these sites are migrating into marine systems at levels that could pose a threat to the environment.

Increasingly, groundwater is recognized as a potentially significant, although poorly quantified, source of nutrients and contaminant materials to coastal ecosystems. Interest in quantifying the exchange between groundwater seepage and overlying surface water has increased due to potential impacts resulting from anthropogenic land uses. Groundwater discharge originates inland and carries with it contaminants or nutrients, dissolved or colloidal, that could impact the chemical budget of surface-water ecosystems. Previous studies clearly show that groundwater discharge into surface-water environments can significantly contribute to the water budget. This chemical and physical impact may be heightened in smaller bodies of water such as embayments or lagoons, due to their limited volume and restricted fluid exchange with the open ocean.

A collaborative effort between the Environmental Sciences Laboratory at Space and Naval Warfare Systems Center, San Diego (SSC San Diego), the Naval Facilities Engineering Service Center (NFESC), and Cornell Cooperative Extension Marine Program was made to develop improved methods for (1) identifying the spatial location where exchange is likely to take place, and (2) accurately measuring the groundwater seepage across the sediment-water interface. This effort resulted in the development of the Trident probe and the UltraSeep system.

The Trident probe is a simple, direct-push system equipped with temperature, conductivity, and water sampling probes. A measured contrast in temperature and/or conductivity between surface water and groundwater can be used to determine potential areas of groundwater impingement into the surface water. The water-sampling probe is used to collect in situ water samples for detailed chemical characterization of contaminants.

Once potential areas of groundwater impingement are identified, the UltraSeep Meter can be used to make continuous, direct measurements of the groundwater seepage rate using an ultrasonic flow meter. The UltraSeep system also contains a multi-sample, water-sampling system that can pump water to six sequential sampling bags mounted around the perimeter of the meter. Conductivity, temperature, and pressure sensors are also mounted on the unit.

In this document, the initial hardware development, testing, and field protocols are described for new techniques used to identify potential areas of groundwater impingement into surface waters (the Trident probe), as well as techniques for quantifying the flow rates and contaminant levels of groundwater at the surface-water interface (the UltraSeep System).

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INTRODUCTION

Coastal landfills and hazardous waste sites pose a potential environmental threat to surface water bodies through the exchange of groundwater-borne contaminants. Many of these sites are located adjacent to harbors, bays, estuaries, wetlands, and other coastal environments. Because of this potential threat, there is a general requirement to determine if contaminants from these sites are migrating into marine systems at levels that could pose a threat to the environment.

Increasingly, groundwater is recognized as a potentially significant, although poorly quantified, source of nutrients and contaminant materials to coastal ecosystems. Groundwater discharge (seepage) into coastal and surface-water environments has been studied extensively using various methods (Lee, 1977; Lee and Cherry, 1978; Taniguchi and Fukuo, 1993; Cable et al., 1996; Moore, 1999; Li et al., 1999; Chadwick et al., 1999; Paulsen et al., 2001; Simmons, 1992; Moore, 1996; Valiela and D'Elia, 1990; Montlucon and Sanudo-Wilhelmy, 2000). The primary driver for seepage in near-shore environments is probably the discharge from land to surface water induced by the hydraulic gradient in the terrestrial aquifer. However, significant contribution to seepage may also derive from groundwater circulation and oscillating flow induced by tidal stage (Simmons, 1992; Li et al., 1999). In coastal areas with strong tides, tidal mixing zones may form from the movement of seawater into the aquifer (Figure 1). This tidally mixed zone can be important in controlling the exchange of groundwater due to a process called tidal pumping (Moore, 1996). Tidal pumping is when seawater mixes with groundwater at high tide, and then as the tide recedes, the mixture of seawater and groundwater is drawn out into the coastal waters. Because this process repeats every tidal cycle, appreciable volumes of groundwater can be extracted over time (Moore, 1996; Valiela and D'Elia, 1990).

Interest in quantifying the exchange between seepage and overlying surface water has increased due to potential impacts resulting from anthropogenic land uses. As mentioned above, groundwater discharge originates inland and carries with it contaminants or nutrients, dissolved or colloidal, that could impact the chemical budget of surface-water ecosystems. For example, Montlucon and Sanudo-Wilhelmy (2000) concluded that groundwater discharge into Flanders Bay on Long Island, NY, accounts for up to 37% of the copper distribution in the bay . They also estimated that seepage accounts for approximately 40% of the total river inputs in a study area in the South Atlantic Bight. These studies clearly show that groundwater discharge into surface-water environments can significantly contribute to the water budget. This chemical and physical impact may be heightened in smaller bodies of water such as embayments or lagoons, due to their limited volume and restricted fluid exchange with the open ocean.

Several measurement techniques have been proposed and implemented over the past 25 years. Lee (1977) made the first breakthrough in quantifying seepage into surface waters. This breakthrough involves a device consisting of a cut-off section of a 55-gallon drum (area, 0.255 m^2) in which the open-end is inserted into the sediment. Attached to the drum via an outflow port is a 4-l plastic bag that collects the seepage. The volume of the bag and sampling interval are recorded and the specific discharge is obtained by dividing the volume of collected seepage by the area of the drum. Although generally quite effective, various errors associated with the device must be corrected before sampling (Shaw and Prepas, 1989; Belanger and Montgomery, 1992). Another disadvantage to this method is that it is quite labor-intensive because the plastic bags must be monitored and replaced continuously.

Cherkauer and McBride (1988) overcame some of these shortcomings by designing a remotely operated seepage meter. Plastic collection bags were used, but separate chambers were installed so that samples could be collected remotely. This meter did not require manual installation, but it was heavy enough to sink into the bottom sediment as it was lowered. The major drawback to this seepage meter was that with a weight of greater than 150 pounds, it was not very portable, could only be used in large water bodies, and might distort flow paths slightly as it was sealed into the bottom

Further advancement of the Lee (1977) technique came from Chadwick et al. (1999). Their meter consists of six chambers capable of automated measurements. Attached to each chamber is a plastic collection bag that collects seepage over a specified time interval. Seepage is collected until all six chambers have taken measurements.

A major advance in quantifying transient seepage came from Taniguchi and Fukuo (1993). Their seepage meter is based on a thermal perturbation technique and can continuously record specific discharge. Although divers are still needed, the deployment and measurement of seepage is much less labor-intensive than previous methods. Another method used by McIlvaine (1998) infers groundwater discharge across the sediment-water interface through pressure gradients using the Portable In-Situ Pore Pressure Instrument II (PISPPI). The pressure gradients are recorded during the recovery of a negative pressure pulse that is generated using a hand-held pump connected to the probe of the instrument. This instrument can also measure the hydraulic conductivity of the sediment.

Building on these historical advances, a collaborative effort between the Environmental Sciences Laboratory at Space and Naval Warfare Systems Center , San Diego (SSC San Diego) and Cornell Cooperative Extension Marine Program set out to develop improved methods for (1) identifying the spatial location where exchange is likely to take place, and (2) accurately measuring the groundwater seepage across the sediment-water interface. In this document, we describe the initial hardware development, testing, and field protocols for new techniques for identifying potential areas of groundwater impingement into surface waters (the Trident probe), as well as techniques for quantifying the flow rates and contaminant levels of groundwater at the surface-water interface (the UltraSeep System).

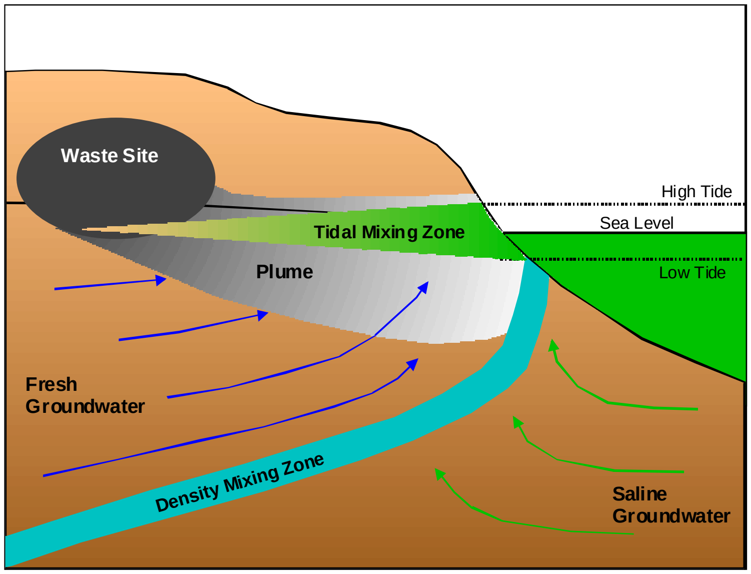

Figure 1. Conceptual representation of coastal contaminant migration process and associated groundwater–surface water interaction.

HARDWARE DESCRIPTION

The Trident Probe

To identify potential areas where groundwater is entering the surface water, we have developed the Trident Probe (Figure 2), a simple direct-push system equipped with temperature, conductivity, and water-sampling probes. Contrasts in temperature and conductivity between surface water and groundwater are used to determine likely areas of groundwater impingement. The water-sampling probe can then be used to collect samples for detailed chemical characterization of contaminants.

The temperature sensor consists of a customized Sea-Bird Electronics, Inc. SBE 38 digital oceanographic thermometer with a ruggedized, 60-cm long titanium probe. The sensor has a measurement range of -5 to +35 °C at an accuracy of 0.001 °C, and a resolution of 0.00025 °C. The sensor response time is about 500 milliseconds. The sensor housing is titanium, with a depth rating of 10,000 meters. Real-time temperature data are transmitted from the unit in ASCII format via RS-232 at a frequency of about 2 Hz. Areas of groundwater seepage may appear either as warm or cold contrast to the surface water, depending on the seasonal and site characteristics.

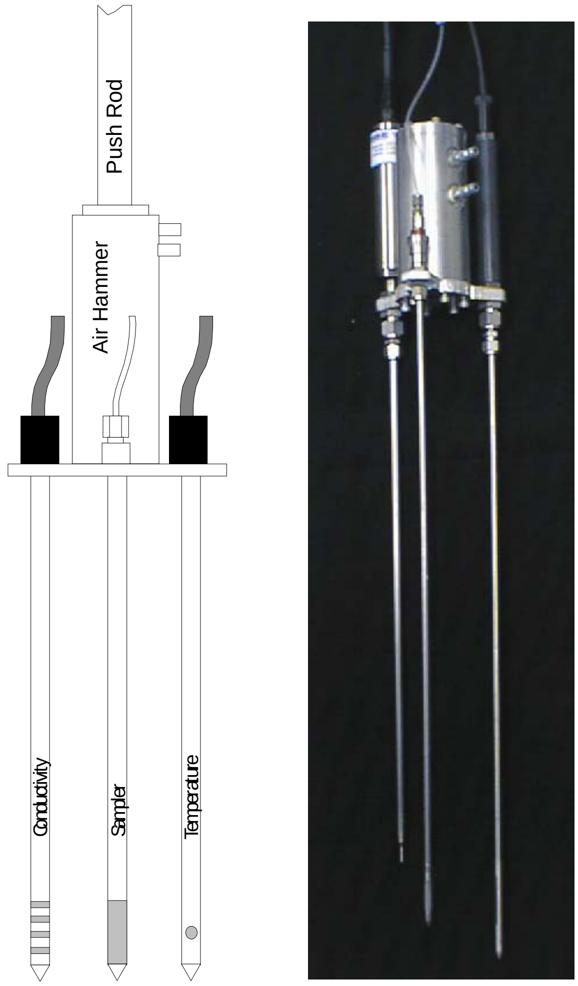

Figure 2. Schematic and photo of Trident probe, showing conductivity, temperature, and water-sampling probes.

The conductivity sensor uses a custom, small-diameter, stainless-steel, Wenner-type probe, 60-cm long. The probe is configured with two pairs of stainless-steel electrodes. A constant current is imposed through the outer pair, and the voltage is monitored through the inner pair. Both pairs of electrodes are coupled through an underwater connecter and cable to a standard Geoprobe® model FC4000 deck unit that controls the outer electrode pair current, monitors the inner electrode pair voltage, and sends the corresponding raw conductivity signal to a laptop computer via an RS-232 port. The laptop applies calibration and temperature corrections to the signal, and records and displays the results. The conductivity signal varies primarily as a function of changes in salinity, and secondarily, as a function of clay content and porosity (Figure 3). Areas of likely groundwater seepage are generally associated with low conductivity, either as a result of low salinity, low clay content (high permeability), or both.

The water-sampling probe allows interstitial waters to be extracted from the sediment at selected depths up to about 60 cm below the sediment-water interface. Porewater is collected by syringe or vacuum pump extraction through a small-diameter, Teflon®-coated, stainless-steel probe (see Figure 2). The probes are ¼-inch-diameter, stainless-steel tubing fitted with a solid point. On the side of the tube near the tip, there is a sample port consisting of a slot covered by a small mesh size (241-μm), stainless-steel screen.

The three probes are collocated in a triangular pattern, with a spacing of about 10 cm on an aluminum mounting base. Coupled to the mounting base is a submersible air hammer that assists in driving the probe into the sediment. On the top of the air hammer is a coupling for a 2-m aluminum push rod that can be sequentially lengthened in 2-m increments to a total length of about 10 m. A bundled cable including the temperature and conductivity signals, Teflon® sampling tube, and pneumatic air hammer hose runs from the probe to the surface. The sensor signals from the temperature probe and the conductivity deck unit are linked to a laptop computer with real-time display via a graphical MATLAB® interface. The Global Positioning System (GPS) is also coupled to the laptop to simultaneously record the sampling locations.

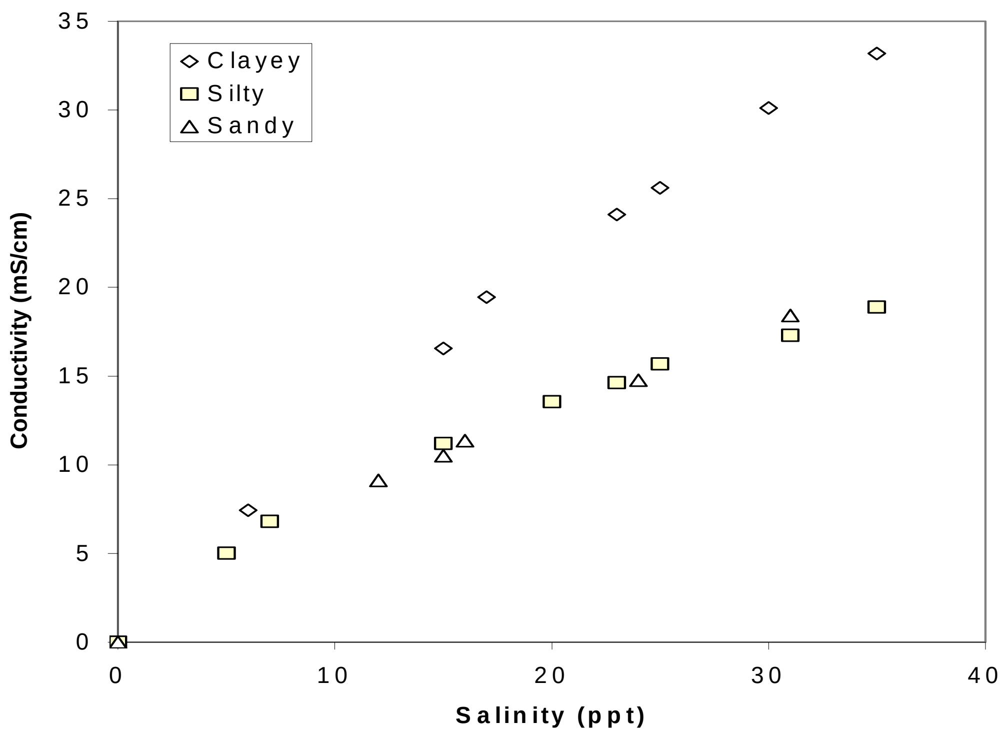

Figure 3. Response of Trident conductivity probe to changes in salinity and sediment type.

In operation, the Trident probe can be deployed in several ways, depending primarily on the depth of the site. In very shallow water (0 to 1 m), the operator simply walks or wades to the sampling station and manually pushes the probe to the desired depth. Experience has shown that the probe pushes easily by hand to a depth of about 30 cm. The air hammer, or a slide hammer, can then complete the push, if necessary. In water of moderate depths (1 to 10 m), the probe is easily deployed from a small boat using the push rod in combination with the air hammer (Figure 4). It is important that the boat be well-anchored to minimize lateral loading on the probe during the insertion. In deeper water (>10 m), a diver can deploy the probe (Figure 5), or it can be attached to a landing frame.

Figure 4. Deployment of Trident probe from small boat using push rod and air hammer.

Figure 5. Diver using air hammer to deploy Trident probe.

The UltraSeep Meter

The UltraSeep Meter combines the continuous, direct measurement of groundwater seepage rates using the time-transient ultrasonic technique described by Paulsen et al. (2001) with a multi-sample, water-sampling system similar to that described by Chadwick et al. (1999). The meter relies on a Teflon®-coated, stainless-steel, open-bottomed chamber measuring 48 x 46 cm to funnel the seepage water to the flow sensor. The flow sensor is connected to the high point of the funnel via 12-mm Teflon® tubing, allowing free flow of water between the funnel and the outside environment. A W.S. Ocean Systems (now EnviroTech) ESM data logger/controller unit monitors data from the flow meter. Based on the measured flow conditions, the ESM activates a water-sampling system that can pump water to six sequential sampling bags mounted around the perimeter of the meter. The ESM also records data from conductivity, temperature, and pressure sensors mounted on the unit. All these components, along with a 12-V submersible battery housing, are mounted within a 74-cm-diameter by 79-cm high cylindrical aluminum frame (Figure 6).

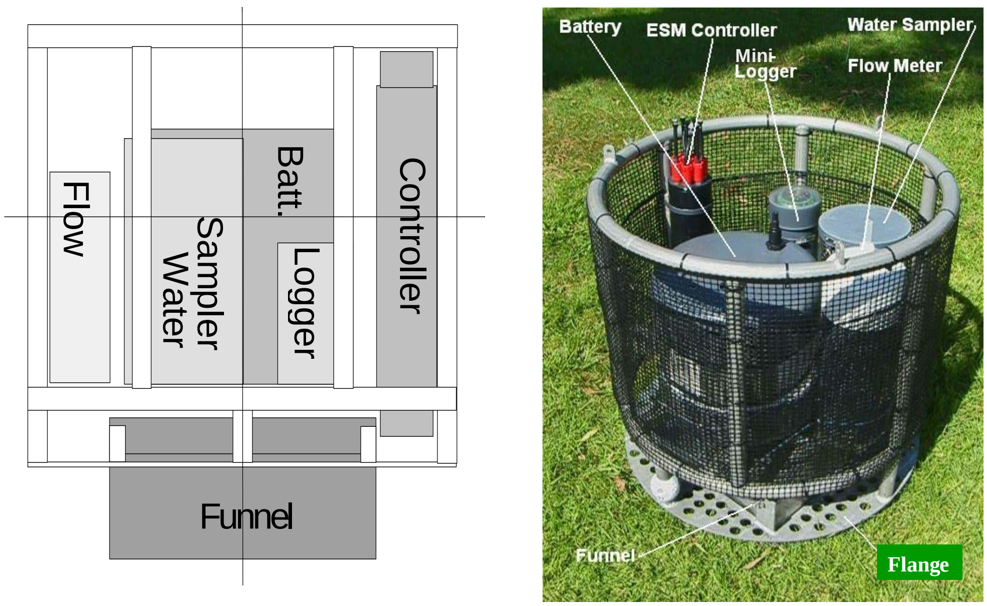

Figure 6. Side view schematic and photo of UltraSeep system.

The ultrasonic flow sensor uses two piezoelectric transducers to continuously measure the travel times of ultrasonic waves along the flow path of the seepage water through the flow tube. As water enters the flow tube, it passes through the ultrasonic beam path. The ultrasonic signal that travels with the flow has a shorter travel time than the signal traveling against flow. The perturbation of travel time is directly proportional to the velocity of flow in the tube. The flow sensor sensitivity is about 1.5 cm^3/min, which, given the amplification from the funnel, translates to a seepage rate of less than 1 cm/d. Signal averaging can improve this sensitivity further. A Teflon®, electrically activated solenoid valve connected in line with the flow tube easily establishes the sensor's zero-flow point.

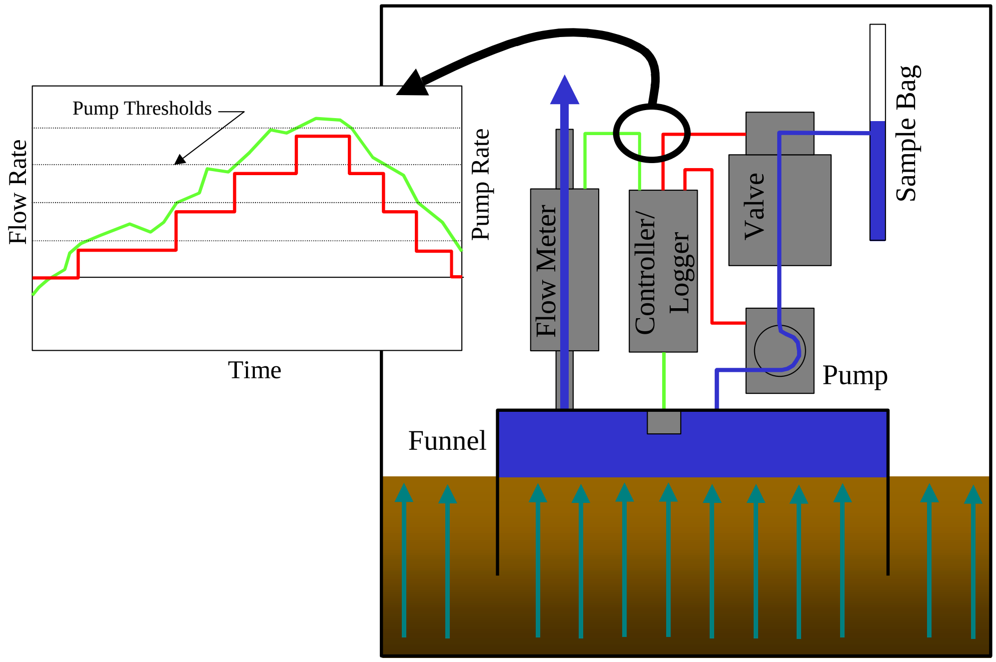

Figure 7. Functional schematic of UltraSeep system, showing the feedback system that regulates water sampling in proportion to seepage rate.

The ESM unit provides the primary data logging and control functions for the UltraSeep meter. The ESM allows programmable logging and control via analog, digital, and RS-232 signals. For the UltraSeep system, the flow sensor data are recorded as an analog signal. Typically, the control program evaluates this signal for a 5-minute averaging time and, based on the laboratory flow calibration, determines the current seepage rate. If the seepage rate is positive, the ESM activates the water-sampler pump via RS-232, and sets the pumping rate slightly lower than the current seepage rate. After a 5-minute sampling period, the flow signal is again evaluated, and the process is repeated. Approximately every 2 hours, the ESM activates the sampling valve via RS-232 and switches to a new sampling bag (Figure 7).

The water sampler consists of a high-accuracy, low-flow–rate, peristaltic pump connected in line with a selector valve. Both units are housed within a submersible pressure case. The pump (Meredos model HP60) allows sampling at user-specified flow rates ranging from about 0 to 18 ml/min. The selector valve (Valco Instruments) has six outlet ports and one inlet port. All water contact parts in the sampling system are constructed from KYNAR® or Teflon® with the exception of the PharMed® pump tubing.

In operation, the UltraSeep meter is lowered to the bottom, either directly from a boat or by divers using a lift-bag. Once the unit is settled on the bottom, divers check the seal. A period of 2 to 3 hours is generally allowed to ensure that any transient seepage response associated with the deployment activities has dissipated. The ESM unit then initiates logging and control functions. At coastal sites, a typical deployment runs over a 12- to 18-hour period to capture an entire semi-diurnal tidal cycle, although the system can be run continuously for about 4 days. During this period, the seepage rate is continuously monitored, and up to six water samples are collected for chemical analysis. At the end of the deployment, the meter is recovered using either a lift line to the recovery boat, or by diver assistance. The meter data are then downloaded and the Teflon® sample bags recovered (Figure 8).

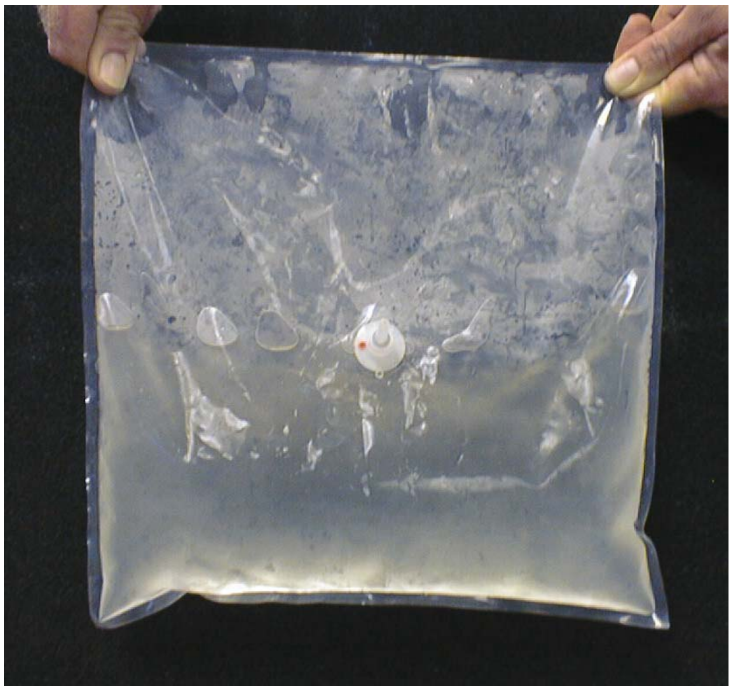

Figure 8. Teflon® sampling bag.

TRIDENT PROBE PROTOCOLS AND PROCEDURES

Planning Deployment

The Trident probe can be deployed in various ways, depending on the site characteristics and resources available (Figure 9). For shoreline sites where sampling occurs onshore or in shallow waters accessible by wading, the Trident probe can be directly inserted into sediments. A segmented push-pole is used to deploy the probe in waters up to 30 feet deep; the pole sections are 6 feet long and can be lengthened or shortened according to depth. Divers can directly insert the Trident probe or it can be mounted into a frame and lowered by surface craft. Each method requires different support equipment, but the following procedures cover the Trident system.

There are five major pieces of equipment required to operate the Trident system: (1) the Trident probe, (2) the communications/pneumatic cable, (3) Geoprobe®'s FC4000 field computer, (4) a laptop computer with the proper system requirements, and (5) a hand-held GPS unit with an RS-232 interface. In many cases, a 12-V deep-cycle car battery and 750-watt power inverter will be required for portable power. Appendix A provides a pre-deployment checklist to ensure all necessary items are considered.

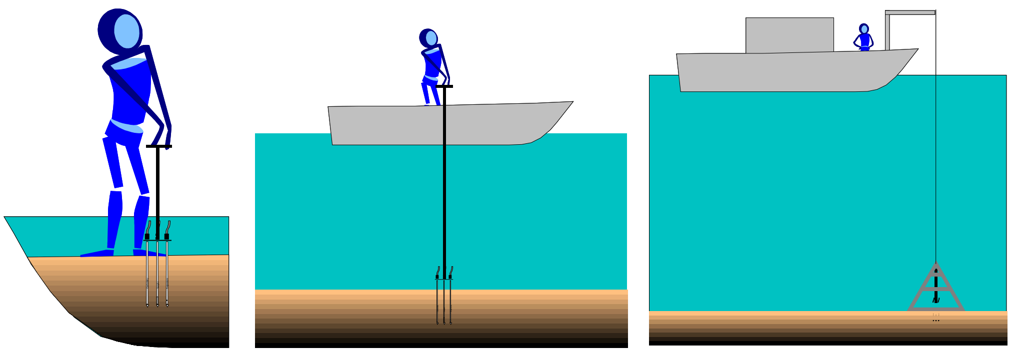

Figure 9. (Left to right) shallow-water (0 to 3 ft) T-bar, mid-range (3 to 30 ft) push-pole, and deep-water (>30 ft) deployment methods for Trident probe. Diver method not shown.

Equipment Setup Procedures

Pneumatic Hammer

The Trident probe may require a built-in pneumatic hammer to insert the probe into sediments and need checking before use. It is important to oil the hammer occasionally to ensure proper lubrication of the hammer. Place several drops of pneumatic oil into the pneumatic hose connector on the input side for every 5 minutes of actual air operation (most pneumatically assisted probe insertions only require several seconds of hammer operation). Also apply a small amount of corrosion preventative behind the sliding collars on the female pneumatic hose connectors before deployment and after rinsing. Attach the regulator to a SCUBA tank and connect the hose to the input connector on the hammer housing, marked "IN". Slowly open the valve on the SCUBA tank to activate the hammer. You may want to hold a towel over the output connector on the housing, as some oil will be ejected. The hammer will vibrate at an increasing frequency as the SCUBA tank valve is opened further, increasing air flow. You do not have to fully open the tank valve to operate the hammer. It is important to make sure the hammer has proper lubrication before storing, to prevent corrosion. You can use a hammer extraction tool (Figure 10) to remove/install the air hammer if service is necessary as described in the Maintenance section of this document.

Figure 10. Air hammer extraction tool.

Trident Cable Assembly

The Trident cable assembly is connected to the probe at the following five points:

- Inlet port on the pneumatic hammer housing
- Outlet port on the pneumatic hammer housing
- Quick-connect for the porewater sampler
- Probe connections for temperature
- Probe connector for conductivity

It is crucial to make sure the pneumatic hose connections are properly made to prevent water from leaking into the hammer assembly and to supply/vent air correctly. A Swagelok quick-connect secures the sampling line to the porewater probe. Use the following procedure to make the pneumatic hose connections:

1. Push the male side of the connector attached to the sampling line into the female connector on the probe until it clicks (this type of connector is open only when the halves are properly coupled).

2. Attach the two cable connectors from the “Y” mold onto the temperature and conductivity probes.

3. Depending on the deployment method, zip-tie the Trident cable assembly to the short pipe extension coming from the hammer housing or onto the first section of the push-pole to prevent stress at the connections.

The surface portion of the Trident cable assembly requires connections at three points:

- Geoprobe® FC4000 field computer for the conductivity probe
- Interface cable for the temperature probe
- Quick-connect on the SCUBA regulator hose

Follow this procedure to make the surface portion connections:

1. Attach the 8-pin connector on the cable coming from the "Y" mold to the connector labeled "PROBE" at the rear of the FC4000 field computer. The f4-pin temperature cable coming from the other side of the "Y" mold is coupled to temperature interface cable having a 25-pin connector at the other end.

2. A 9-V battery connected to a mount on the adaptor cable provides power for the temperature probe. Secure battery to cable with zip-tie or tape.

Laptop Connections

A quad serial card is used to interface the GPS unit, the temperature probe, and the Geoprobe® FC4000 field computer with the laptop. The quad card connections are as follows:

- COM 4 to RS-232 serial splitter cable to the GPS 9-pin serial cable to GPS unit
- COM 5 to 25-to-9-pin RS-232 serial cable to temperature interface cable
- COM 6 to RS-232 serial cable to "COM 2" on back of FC4000

Geoprobe® Field Computer

The Geoprobe® FC4000 field computer is the standard unit Geoprobe® uses for their larger commercial conductivity probes. The unit powers the Trident conductivity probe and translates conductivity signals to numerical values for output to the GUI laptop. The conductivity probe is constantly powered by the FC4000 and data continually stream from the COM 2 serial port on the back of the unit. The real-time conductivity data are only viewed on the GUI when the "Activate Probe" button is selected, and are collected when the "Capture" button is used.

Turn on power to the FC4000; the switch is on the rear panel. The contrast dial on the front may have to be adjusted if no image is on the screen. The following menu will appear:

- Select an Option (select #1, conductivity)
- Select a Probe Option (select #1, SC400)
- Select an Option (select #2, to bypass all tests)
- Select Rod Length Used (select #2, for 2-foot rods)
- Select an Option (select #1, for wenner)

You will see a Conductivity versus Depth graph appear on the screen. When the FC4000 is used with the Trident GUI, this graph screen remains blank. To see the data plotted on the FC4000 graph, turn on the “Trigger” switch on the front of the unit and connect the “stringpot” switch to the rear of the unit. Conductivity data are plotted on the graph when the “stringpot” switch is activated. The depth data that appear are not representative of the probe depth but can serve as a reference to the data collected (due to the application of the Geoprobe® FC4000 with a custom probe).

Trident GUI

A MATLAB® GUI has been developed to simultaneously capture data from the Trident probes and GPS unit for real-time mapping of conductivity and temperature (Figure 11). Install this software onto a laptop with the proper requirements to run MATLAB®. “Chart View®,” which is an electronic navigation software, can be added to the laptop for navigation. If the temperature/conductivity plotting capabilities are required, you must create a digitized chart of the area. Several windows on the GUI display real-time values and graphs of temperature and conductivity along with a map display of sampled locations with their values (temperature or conductivity) represented by colored graphics (Figure 9). The Geoprobe® FC4000, the temperature probe, and the GPS unit must be powered before the “Activate Probes” button is selected on the GUI (see Appendix D for detailed GUI operations).

Individual files are created each time the “Capture” button is activated. Filenames are created using the “Station ID” entry followed by the date (automatic). All time references are based on the time set in the laptop computer. Before capturing data, it is important to allow approximately 1 minute for the temperature and conductivity probes to respond. Observe the temperature and conductivity graphs to see when the readings stabilize before capturing data.

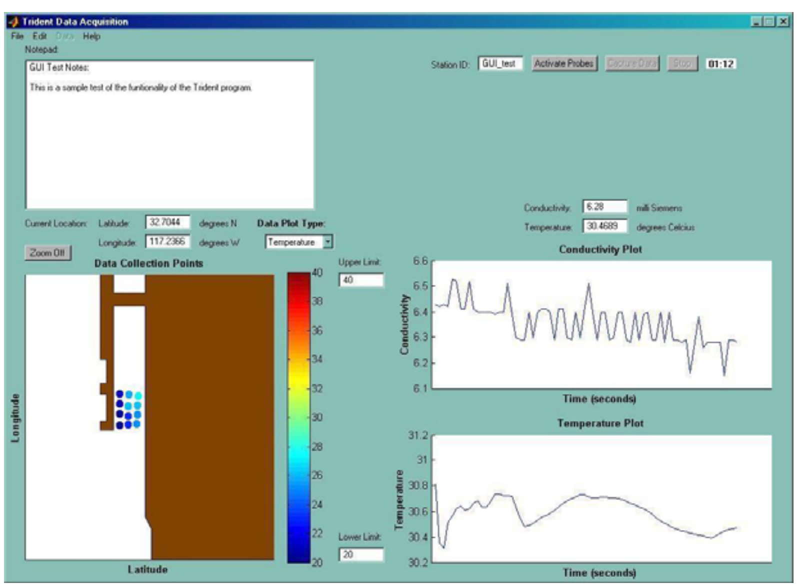

Figure 11. Trident GUI display showing map of survey area with color-assigned values at GPS-referenced sample points.

Deploying Trident Probe

The Trident probe can be deployed by using a push-pole, a diver, a deployment frame, or simply by hand. The deployment method depends on the site characteristics and resources available. For above water and shallow water sites accessible by walking or wading, a sled, vehicle, or cart containing all the support equipment allows transport of the Trident system along a shoreline. The push-pole deployment method can be used from a small boat in water up to 30 feet deep and diver or frame deployment can be used in deeper water.

Shore Deployment

For shore-based deployments, configure the electronics of the Trident system on a stable and portable platform. Although the hand-held GPS can move several feet from the main electronics to mark a position, an extension cable on the GPS unit allows more flexibility when moving from sample point to sample point. This flexibility can also be accomplished by using an external antenna with a longer cable. Once the Trident cable assembly has been connected to the probe and the system is ready to display data, the Trident probe can be inserted into the sediment by hand at depths up to 2 feet. A threaded push-pole can be attached to the probe for wading operations.

Push-Pole Deployment

Trident probe deployments in water depths up to 30 feet deep can be performed from a small boat using the push-pole method. Six-foot sections of pole are combined to accommodate depth and can be assembled as the probe initially descends and decoupled upon retrieval or left intact. Configure the push-pole to remain attached to the probe when set in soft sediments, but configure it to detach from the probe when set in firmer sediments. In this configuration, the probe is retrieved via the cable assembly (see below).

Rigid Coupling

Deploying the Trident probe while leaving the push-pole attached presents certain conditions that require attention. You must remain stationary over the site to prevent lateral forces on the probe if the push-pole is physically held while the Trident probe is operating. A 3-point anchor can hold the probe; anchors can be set past each end of the transect, another set perpendicular (astern), and lines made taunt. Positions can be adjusted along the transect by slacking one anchor line and pulling in on the other. In many cases, once the Trident probe has been set into the sediment, the push-pole will remain vertical after release, as long as the height of the push-pole above the water surface is kept to a minimum. If this is the case, the boat position should be maintained close to the push-pole without the possibility of drifting into the pole or pulling the Trident probe out of the sediment via the cable assembly.

Detachable Coupling

To decouple the push-pole from the Trident probe, the short section of pipe with two short rods protruding from each side is threaded onto the top of the air hammer housing. The initial push-pole that attaches to the Trident probe for this purpose has slots that engage these rods with a counterclockwise push-and-twist motion (Figure 12). A spring, tethered to the pole connector, is placed between the two connectors before being coupled. This spring keeps the probe attached until probe placement is completed. A clockwise twist on the push-pole disengages the probe. The pole can then be pulled from the water while the Trident probe remains in place. This bridle relieves stress on the probe connections when the cable assembly is used to pull the probe back to the surface. A stress relief bridle on the hammer housing is fastened to the cable assembly, which leaves slack on the probe connections when taunt.

Figure 12. Detachable push-pole coupling.

Setting Trident into Sediment

Lower the Trident probe with the push-pole while maintaining minimal slack in the cable assembly until it contacts the sediment and continue to push the probe until it is set. In firmer sediments, you must use the air hammer to assist the insertion. Turn on the SCUBA tank valve while pushing on the pole until the Trident probe can no longer be inserted further. You can bend the probes if objects are buried in the sediment. Hard objects such as rocks can be felt via the push-pole. Reposition the Trident probe if there is any question of striking hard objects. If the Trident probes get bent, they can be easily straightened by hand.

Diver Deployment

The Diver method for deploying the Trident probe offers rapid repositioning between sample locations but requires communication between topside and the divers. An underwater communications unit allows verbal communications between divers and Trident GUI operators, but simple signals can be worked out if an underwater communications unit is not used. A partially submerged metal pipe struck by a hammer can produce audible signals for communications to the divers. A buoy with a line held by a diver can be bobbed on the surface for return visual communications. Communications would be necessary for repositioning the Trident probe, actuating the air hammer, and for confirming placement. A measuring tape or marked line marks a transect along the bottom and guides the divers positioning the probe. The Trident probe is set up with a short section of pipe threaded into the hammer housing so it can be used as a handle.

Frame Deployment

The Trident probe can be mounted into a frame for deployment from a support vessel's davit. Although this method was never used during development, the concept is straightforward. A 4-foot pipe, threaded into the top of the Trident air hammer housing, passes through a plastic guide at the top of a 3-foot high deployment frame. A locking pin, placed through a hole in the pipe above the guide secures the Trident probe within the frame when out of the water. A shackle attached to the top of the pipe connects the davit cable. Once the Trident probe and frame are suspended for deployment, the locking pin is removed. The Trident is lowered to the bottom and the air hammer is actuated for insertion.

Porewater Sampling

The Trident probe allows the collection of porewater at the same depth the conductivity and temperature are measured, up to 2 feet into sediment. Attach the priming syringe to the closed luer-lock valve on the 1/8-inch Teflon® tubing coming out of the cable assembly, pull vacuum on the syringe, and lock the plunger using the locking rod (Figure 13). Open the luer-lock valve and allow the priming syringe to collect 50 ml of water to prime for sample. If 50 ml of water is not collected, close the luer-lock valve, disconnect the syringe, empty, and repeat vacuum until a total of 50 ml has passed through the sampler. Repeat this process with the sample syringe, evacuating air from syringe only if necessary, until sample size is acquired. Larger porewater collections can be made using a sample bottle plumbed between the Trident sampler and a vacuum pump. Note that some sediments are not conducive to direct porewater sampling due to fine grain size. It may help to push a few milliliters of water through the sampler, using the priming syringe as the probe moves down through the sediment.

Clean the porewater sampler before each sample collection. Place the tip of the porewater sampler into a collection container and push 100 ml of warm Alconox® solution (2%) through the sampler with a specified syringe. Follow this cleaning with 100 ml of deionized (DI) water, using a syringe dedicated for this purpose.

Figure 13. Syringe with locking rod through plunger.

Maintenance

Thoroughly rinse off the Trident probe and cable assembly while all probe connections are still in place. Pay particular attention to the pneumatic fittings. Put the porewater probe tip in a container of freshwater and, using the priming syringe, draw at least 100 ml of freshwater through the porewater sampler to rinse and remove any particulates. Remove the probe tip from the container and draw remaining water from the sampler and line. If the sampling line was exposed to any free product, you should flush line with warm Alconox® before rinsing. Disconnect cable assembly and place a few drops of oil into the air intake port of the pneumatic hammer. Apply an anti-corrosive to the pneumatic quick-connects.

The pneumatic hammer should provide long service when properly lubricated and protected from water entry. If you must access the hammer, remove the top cover plate on the housing and use the air hammer tool to unscrew the hammer assembly. The hammer assembly has only three parts: the cylinder, the piston, and the valve body. Lift the valve body off the hammer cylinder to access the piston. Clean and lubricate the piston and cylinder with light oil. Apply grease to the threads on the cylinder, replace the valve body, and use the air hammer tool to screw the hammer assembly into the housing.

ULTRASEEP PROTOCOLS AND PROCEDURES

Planning Deployment

Planning the deployment period of the UltraSeep is important, as maximum seepages occur during periods of extreme tidal cycles. If a single tidal period of approximately 12 hours is sampled, Start the sampling sequence at the beginning of the high tide. If sampling occurs over several days, you might want to start the sampling sequence just before a high or low tide.

Before heading out to the field, make sure you have all necessary items for the deployment. Appendix C covers all the items required for using the UltraSeep. Set up programs for the UltraSeep before fieldwork so that pre-deployment programming goes quickly. Clean UltraSeep surfaces that come in contact with sample waters (sample tubing and interior of funnel) and attach sample bags before deployment.

Battery Charging

The UltraSeep uses the latest in battery technology to power the meter up to 4 days while providing exceptional safety during transport and handling. A 12-V, 105-Ah, deep-cycle, aggregate glass matt, sealed battery supplies power. While this type of battery technology minimizes off-gassing, **vent the battery housing while charging** to prevent explosion (also remove the threaded plug at the top of the housing during storage). Before charging, remove the threaded plug from the top of the battery housing and insert tubing at least 10 inches into the housing (Figure 14). This tubing can be connected to a low-flow air source or an aquarium air pump, which provides a positive airflow during the charging phase.

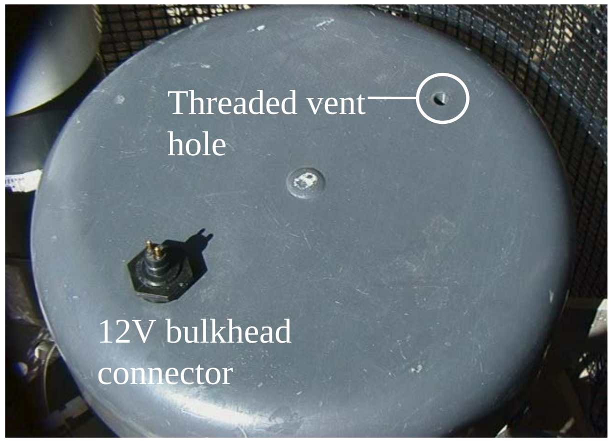

Figure 14. Top of the battery housing showing power connector and vent hole (without plug).

To maintain optimum battery performance, the battery should be fully charged before storage and recharged once every 4 months. The charging unit, a CT Chargetek 500, is fully automatic and can be left on charge indefinitely, without damaging the battery. First, connect the charger to the battery via the 2-pin connector on the top of the housing. These connector pins are “hot,” so prepare the area so that nothing will inadvertently short the pins, which could cause permanent battery damage and a possible explosion. Once the charger is connected to the battery, plug the unit into a standard 115-V outlet. It is highly unlikely, but if the “service” light on the charger illuminates, unplug the charger and test for possible causes. The red “fast” charge light will remain on until the battery has received sufficient charge and the light illuminates green, indicating a “float” charging phase. It is preferable to leave the battery charging on “float” for several hours, but is not necessary. Unplug the charger from the AC outlet before disconnecting the charger from the battery. Inspect the threaded plug at the top of the battery housing and wrap it with Teflon® tape before re-installing.

Preparations for Cleaning

The solutions used for cleaning the UltraSeep will differ according to the type of analysis performed. A warm 2% Alconox® solution is used in the cleaning process in preparation for sampling organic compounds (most common use) and a warm 2% Rutherford Backscattering Spectroscopy (RBS) solution for sampling metals. Nitric acid is used if metals are going to be measured and must be diluted to a concentration of 10%. The last fluid used in the process will be 18 mega-ohms of DI water. Teflon® sample bags are attached to the DI primed sample lines once the cleaning process is complete. See Appendix E for detailed cleaning instructions.

Make sure the pump tubing inside the valve housing has been loaded into the pump head. Try not to disturb the knurled screw on the pump head; this screw controls the pressure of the rollers on the tubing and affects flow. The adjustment screw should be set to the manufacturer’s specifications, but a 1¼ turn open from the full stopped position should be close.

Software

Two programs are needed for programming the ESM-1 controller/logger and one for the MiniLogger. A text editor is needed to write/change the programming scripts for the ESM-1; the developers of UltraSeep use ConText Editor. The other is Hyperlink, which communicates with the ESM-1. Programs to run the ESM-1 for actual sampling are the “main” and “pump” files. Other programs are provided for decontaminating the meter, and for valve and pump testing. A program named “[illegible]wm” is used to program/communicate with the MiniLogger. Create desktop shortcuts to find these programs easily.

Preparing to Communicate with Meter

Two components on the meter require computer programming before deployment. One is the ESM-1, a data logger/controller for the valve and pump, and the other is the MiniLogger for the ultrasonic flow meter. To communicate with the meter, the power cable on the meter must be connected to the battery. To connect a computer to the ESM-1, plug the wet-pluggable mini-connector cable from the small interface box into the ESM-1 (serial port 1) and the RS-232 (DB-9) connector from the interface box into the computer (Figure 15). The computer connection for the MiniLogger is made via the 100-foot MiniLogger communications/solenoid cable that has a “T” mold going to two shorter cables. One of these short cables, labeled “com mini”, is then connected to the “mini logger com” cable having the DB-9 computer connector. Plug the female 3-pin connector on the 100-foot cable into the male 3-pin connector on the MiniLogger and the DB-9 into the computer. A cover for the display panel on the MiniLogger must be left in place when outside, as sunlight affects the display and makes it unreadable until the panel cools.

The ultrasonic flow meter requires “zeroing” once the UltraSeep is submerged; this procedure ensures accurate flow measurements and should be conducted for each deployment. A 24-VDC source is needed to supply power to the solenoid valve, plumbed in-line with the flow sensor. To activate the valve,. two, small, 12-V gel cell batteries connected for 24-V output can be used. While the solenoid valve is powered (closed), the water inside the flow tube is not moving and the flow meter can be zeroed. An adaptor cable has two leads for battery connections and is connected to the short cable coming from the “T” mold, labeled “solenoid 24V”.

Figure 15. ESM-1 computer interface.

Programming UltraSeep

Program the MiniLogger before the ESM-1. Check the display panel on the top of the MiniLogger to make sure it is getting power; characters will be visible. Select the "Shortcut to Flowm" from your computer's desktop. Zeroing the flow sensor should be done after the MiniLogger and ESM-1 are programmed and the UltraSeep is in the water. See Appendix H for "zeroing" and programming procedures for the MiniLogger.

Once the MiniLogger has been programmed, connect the ESM-1 interface box from the computer to serial port 1 of the ESM-1. If remote monitoring of the ESM-1 is desired, connect the 100-foot com cable between the interface unit and the ESM-1. Two files are uploaded to the ESM-1 for programming; these files are the "main" and "pump" files. The "main" file is edited and used to program the delay and sampling times, while the "pump" file is edited and used to control the pump. Details for programming the ESM-1 are in Appendix G. Log the ESM-1 start time as well as the start time for the sampling sequence to determine sample periods for each sample bag and when the sampling sequence will finish.

UltraSeep Deployment

Review the pre-deployment checklist in Appendix D and ensure that the valve stems to the sample bags are in the open position. Remove wheels from the UltraSeep frame once the unit is suspended. Traditionally, divers have been used during deployment of the UltraSeep to facilitate priming the ultrasonic flow tube and ensuring a good placement into the sediment. Typically, the UltraSeep has been deployed into the water using a winch and release shackle attached to the meter's lift bridle. If the sediment site looks good for deployment directly under the UltraSeep, then it can be lowered to the bottom as long as the support boat is operating in calm waters. Lift bags are usually used and allow divers to maneuver the meter to a suitable location (Figure 16). It is important that the divers do not allow air bubbles to enter the funnel.

Zero Flow Meter

The ultrasonic flow sensor should be "zeroed" to provide accurate flow data. It is very important to prime the ultrasonic flow tube using the primer bulb to remove any air bubbles in the tube or under the funnel before zeroing. The funnel should be cleared first, followed by the flow tube using the suction side of the priming bulb. A 24-V source is attached to the MiniLogger cable to close the in-line solenoid valve during the zeroing process.

The zeroing procedure can be performed after the UltraSeep has been set into the sediment. Use this method of zeroing if bottom-water temperatures are significantly different than temperatures at the surface. This method of zeroing requires the MiniLogger cable to remain attached to the meter. Once completed, cable ends are dummy-plugged before tossing the cable into the water. Use other zeroing options if it is preferable to deploy the UltraSeep without leaving cables attached. The unit can be suspended near the bottom while the flow sensor is zeroed, or it can be zeroed just under the surface if temperature and salinity are similar to benthic waters. Once zeroed, the UltraSeep can be brought onboard and the cables removed and dummy plugs put on connectors. Priming the flow tube and removing bubbles from the funnel will have to be performed again.

Figure 16. Diver using lift bag to deploy UltraSeep.

Setting UltraSeep

Gently lower the meter into the sediment to avoid disruption. The flange should be set level with the sediment surface. If sediments are extremely soft, it may help to have the lift bags or dive vests slightly more buoyant for a controlled push into the sediment. If force is required to insert the UltraSeep, use vertical pushing or “bouncing” on the meter frame. Use a slight back-and-forth rocking motion on the frame as a last resort. Relocate the UltraSeep if an object under the sediment surface interferes with placement. The idea is to place the meter into the bottom while minimizing disturbance of the sediment (Figure 17).

The UltraSeep can be marked with a buoy, provided there is enough slack in the line to account for high tides over the course of the experiment and there is no threat of boat traffic or people to disturb the marker buoy. This marking also allows for recovery without the need for divers. The unit can also be tethered to a structure, such as a nearby piling, if marker floats are risky and recovery without divers is planned. In many situations, a marker float or tethered line attached to the meter is undesirable, but the meter can be relocated using a GPS unit or marker buoy anchored adjacent to the meter. If lines are attached, the possibility of the UltraSeep being disturbed must be considered a possibility and could affect measurements and samples.

The meter may also be deployed from shore if the waters are too shallow for a boat deployment. In this case, it may be useful to place the meter placed onto a makeshift sled to transport it to a location deep enough for the UltraSeep to operate (25 inches deep at lowest tide). Another option is to remove the battery from the frame to lighten the UltraSeep and power the meter from shore via the 100-foot power cable. The battery, if left on the frame, helps stabilize the meter and minimize any physical disturbances from passing waves and wakes. If the remote power method is used, consider water conditions.

An ambient water sample collected near the sediment surface, close to the UltraSeep location, is also recommended for a "baseline" chemical reference. Divers can make the water sample collection immediately before insertion of the meter or after suspended sediments have cleared.

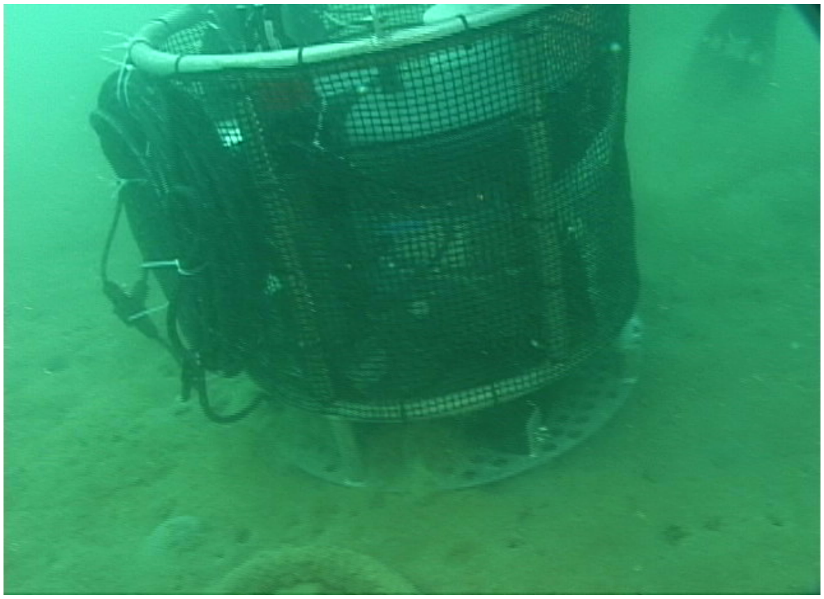

Figure 17. Seepage meter set into sediment up to flange.

Data Collection and Analysis

Downloading Data

Connect computer(s) to the ESM-1 and the MiniLogger as previously described in "Preparing to Communicate with Meter." Procedures for downloading data from the meters are in Appendix H. Check to confirm that the position of the selector valve cycled properly. Use the "openpipe" function after downloading data to make sure that data are on port #6 (see Appendix H).

Plotting Data

Microsoft® Excel is used to process the ESM-1 and MiniLogger data. A template file, "Seep meter Excel Template.xls," processes the ESM-1 data. A template for the MiniLogger "Minilogger Excel Template.x," processes the raw ultrasonic flow data.

ESM-1 data processing instructions are on the “raw data” sheet of the “Seep meter Excel Template” and the “processed” sheet of the MiniLogger template. Data processing instructions are in Appendix I for the ESM-1 and Appendix J for the MiniLogger.

Maintenance

Thoroughly rinse the UltraSeep with freshwater after retrieval, including the interior of the funnel. It is important to flush the inside of the ultrasonic flow tube; Use a garden hose placed over the outlet tube on the top of the housing, flush the inside. Rinse the sample tubing with DI or freshwater by extending the disconnected inlet sample line going to the funnel. Place the extended line-end into freshwater and run the “1minPump.esm” program or the “Clean4.esm” program for a longer flush.

Fully charge the battery after each use and, periodically, to maintain battery strength; refer to the “Charging Battery” section.

It is highly recommended that you unload the PharMed tubing from the peristaltic pump head to prevent permanent deformation and weakening during long storage. Inspect this section of tubing before deploying the UltraSeep, especially if it has been stored in a loaded state or if it is getting old. Check housing O-rings periodically; clean and silicon grease them, if necessary.

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APPENDIX A: Trident Checklist

Water Sampling					
• Adaptor tubing (Tygon)					
• Syringes (vacuum pump?)					
• Vials & label					
• Refractometer					
• Alconox® and DI water					
• Haz Waste Container					
Temperature Measurement					
• Serial Adaptor Cables					
• Battery (9V)					
Conductivity Measurement					
• Field computer – FC4000					
• RS-232 adapter cables					
• Floppy disk					
• Stringpot cable					
GPS 48					
• Site GPS coordinates					
• Spare battery (AA) (4)					
• RS-232 extension cable					
Trident					
• Cable Assembly					
• Push-pole sections					
• SCUBA tank(s) and reg					
• Pneumatic oil					
• Trident kit box					
Boat Stabilization					
• Anchors (3)					
• Lines (3)					
Laptop					
• Power cord					
• Quad serial card					
• RS-232 adapter cables					
• MATLAB® program					
• Local e-chart Chart View					
Other/Misc.					
• 12-V car battery					
• 750-W power inverter					
• Teflon® tape and zip ties					
• Cart & secure lines					
• Tarp					
• Logbook					

APPENDIX B: Trident Software Operational Instructions

Introduction

This document contains and describes the operational instructions for using the Trident Probe Software. It is not meant to be a reference source for the corresponding MATLAB® source code.

Setup And Installation
To run the Trident Probe software, at least a basic version of MATLAB® must be installed. The Trident Probe software does not use any special MATLAB® toolboxes, however the software was written using MATLAB® version 6.0.0.88 (R12) and should probably be run on similar versions as internal functions and functionality changes that occurred with subsequent releases might cause parts of the software to not function correctly.

MATLAB Installation
For specific instructions on installing MATLAB®, please see the MATLAB® documentation.

The Trident Probe Software Installation
The Trident Probe software (the MATLAB® m-files and such) is currently located in the C:\trident directory on the **trident-one** computer. The only subdirectory actively used by the software is the data_files directory. After a data capture is performed, the data are written to flat files in this directory that must exist before running the data capture portion of the Trident Probe software.

In addition, the Trident Probe software help files are located within MATLAB®'s directory structure so that they can be read from within MATLAB®. On **trident-one,** these files are located in the C:\matlabR12\help\trident directory.

Some third-party files existing within the Trident Probe software directory are also needed: the .bln files are the map files. Currently only sdbay.bln exists, but contains the latitude/longitude coordinates for San Diego Bay. The uigetfiles.* files can be used to display an open files dialog and allow the user to select more than one file. This file will be useful in creating an application to read the raw data files generated by the Trident GUI.

Running The Trident Probe Software

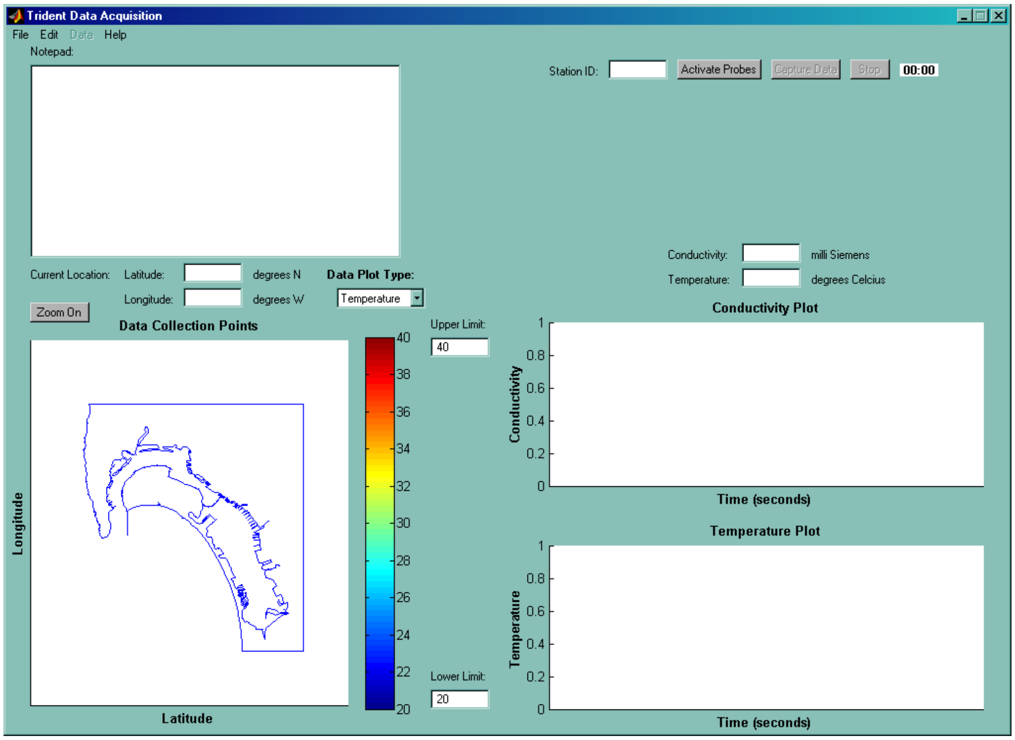
Launching the Program
To run the Trident Probe software, first launch MATLAB®. Then, if the file, trident.m, is not located in MATLAB®'s search path, you will have to add it to the search path to keep from manually having to change into the C:\trident directory every time you start MATLAB®.

To add it to MATLAB®'s search path, follow these steps:

1. From the main MATLAB® window, click **File >> Set Path**.
2. Click the **Add Folder** button.
3. Using the navigation window that pops up, navigate to the directory you wish to add to MATLAB®'s search path. In our case, probably C:\trident.
4. Click **OK** to accept the selected path.
5. The previously selected path will now appear at the top of MATLAB® search path list.
6. Click **Save** to save the changes.
7. Click **Close** to exit the Set Path window. **Note: all changes take effect immediately**.

At this point, if the path was set up correctly and all the files are located in the specified directory, the Trident Probe software should be executable by typing the word 'trident' at MATLAB®'s >> prompt.

The Trident Probe GUI should now be displayed as shown below:



Configuring the Trident Probe Software Preferences

The user should probably configure any preferences he/she would like before running the data collection portion of the program. Click **Edit >> Preferences** from the menu bar.

The preferences menu displays as shown in the figure below.

If the Trident Probe software is being run for the first time, the default settings display. After changes have been made and saved, a file called preferences.mat is created and loaded on subsequent launchings of the Trident Probe software. If this file is ever deleted, the default settings are once again used.

If COM port changes are made, as noted above, they are immediate. For this reason, the availability of the preferences menu is disabled during data acquisition.

The user can select the default map that displays upon the starting of the application. This display is useful if the application is being heavily used in a certain region and keeps the user from having to continuously manually change the location map. A small picture of the map should display in the window to let the user see what the selected map looks like.

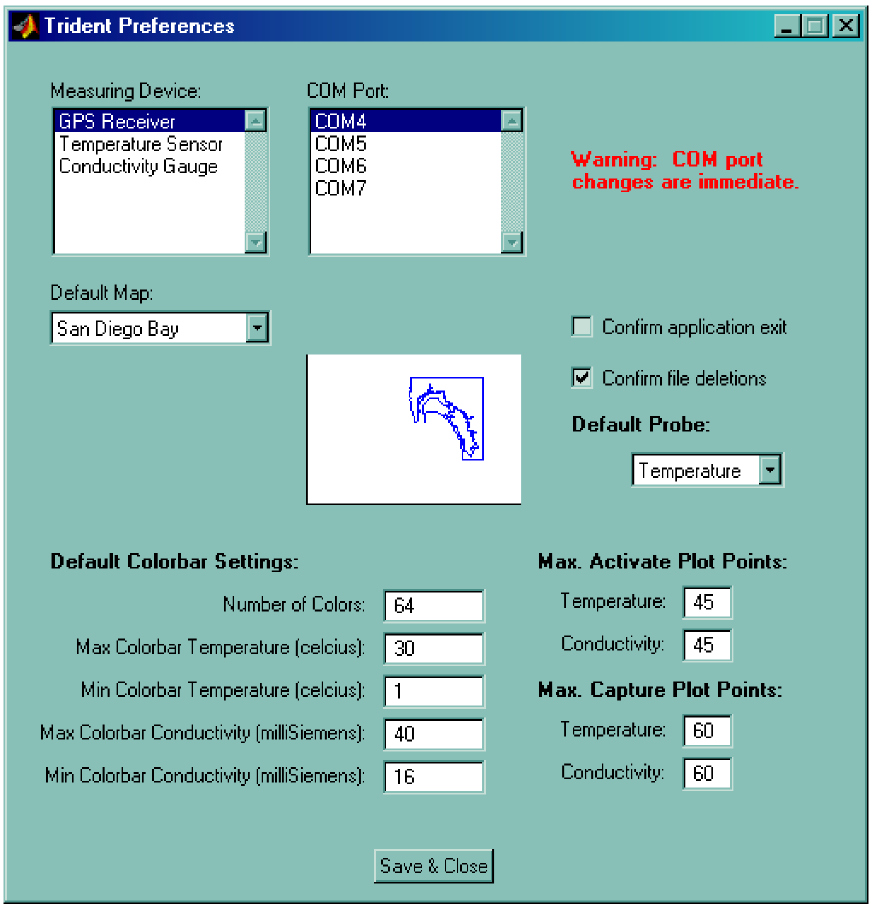
Two checkboxes are to the right of the map display. The first checkbox defines whether the application should prompt the user before exiting. The second checkbox defines whether or not the application confirms file deletions.

The default color bar settings allow the user to choose the number of colors used by the color bar. The higher the number of colors means a smoother transition (i.e., “fading” from solid red to solid orange) between data values, but also means that “close” data values will have very similar colors. The lower the number of colors means a very choppy and abrupt (i.e., jumping from solid red to solid orange) transition between data values and means that even close data values may appear completely different or have identical colors, depending on where the color index lies in comparison to the data set.

It also allows the user to specify the minimum and maximum default temperature settings for the temperature and conductivity plots. These values can also be set via the main Trident Probe software window. These values, if changed, are saved to the preferences file.

By changing the Default Probe setting, users can specify what data they want to plot. They can also change what they want to plot via the main Trident Probe software window, but unlike the min/max temperature/conductivity values, this change is not saved to the preferences file.

Finally, the user can specify the maximum number of data points allowed in the temperature and conductivity plot windows. Two sections exist, one for when the probes are active, and the other for when a data capture is performed.



Capturing Data with the Trident Probe Software

Before data capturing can be performed, the three necessary serial devices, the GPS receiver, the Temperature probe, and the Conductivity probe should all be powered on and ready for use. In the case of the GPS receiver, tone must ensure that the device has acquired the needed satellite signals and is ready for use. The necessary cabling must be connected to the Trident probe. **Thorough and detailed instructions on how to connect and power these devices begin on page 11 of this document.**

To begin the data capture, the probes must first be activated. To do this, click the **Activate Probes** button. **Note that data capture refers to the actual portion of running the software where the software is writing the data to the flat files (and when finished will display the color shaded plot accordingly).**

Probe activation, merely means the probes are turned on and the data transmitted via the serial cables is being received and plotted by the software. While the probe activation should be done after the Trident Probe has been deployed and is firmly in the sediment, it is not required. If this is not the case, the GPS reading taken at the onset of the probe activation may differ from the actual GPS reading taken at the onset of the data capture.

With the probes activated, the Temperature and Conductivity plots will begin plotting the data transmitted from the probes. The Conductivity reading should stabilize rather quickly, while the Temperature plot might need a minute to stabilize. Temperature stability is essential for capturing correct and valid data because during the data capture phase the data from the probes are written out to the flat files at 1 Hz. The same data is saved internally to MATLAB® and used to calculate and create the color-shaded dots in the Data Collection Points window, which are averaged over the entire span of the data capture, i.e., the temperature curve should decay exponentially before stabilizing. If the data capture is performed while the probe readings stabilize, the average value computed by MATLAB® will be higher than the real-world value because the higher values on the decaying portion of the exponential curve have been used to calculate the average. Once the temperature readings have stabilized, i.e., the graph is essentially horizontal, a successful (meaning the data collected will be true and valid) data capture can be performed.

Currently, the MATLAB® code for the Temperature and Conductivity data plots is hard-coded to hold 30 data points before scrolling off the plot.

To begin the data capture, make sure a Station ID has been specified and click the **Capture Data** button. The current location/date/time will be received from the GPS receiver and stored. The location values display in the relevant fields in the GUI. The data plots clear and the internal Temperature and Conductivity buffers reset to zero. At this point, the software collects and plots the transmitted data at 1 Hz. The data is plotted to the Temperature and Conductivity plot windows and also written out to the flat files. The timer in the upper left corner display how long the data capture process has been running and when sufficient data have been collected for this point (usually no more than a minute); click the **Stop** button to end the data acquisition process. At this point, the flat files will be closed for writing and the average temperature and conductivities will be calculated. Depending on what plot type is specified for the Data Collection Points window, a color-shaded dot representing either the Temperature or Conductivity will appear at the location specified by the GPS reading. For this reason, a map of the harbor or coastline where the Trident has been deployed is useful for telling the user where exactly the data point is located. The flat files are stored in a subdirectory from the Trident files called **data_files**. The filename format is the Station ID followed by a date/time stamp. The extension placed on the file is .raw, for raw data.

This process can be repeated for as many locations the user needs to evaluate. Currently, the map image with the color-shaded points cannot be exported to a picture file, except as a "Print Screen" option.

Other Trident Software Options

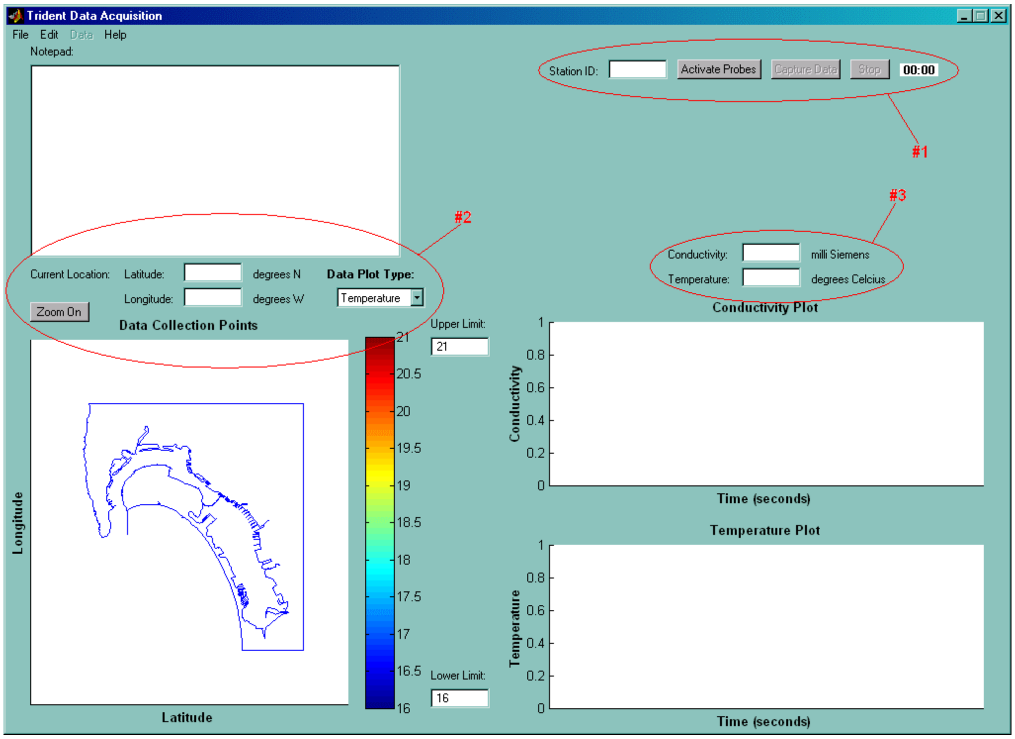
The Data Collection Points window has a zoom feature that, when enabled, allows the user to zoom in on specific areas. This feature is extremely useful if a coastline or harbor map is being used as the user can then zoom-in on the data points collected and see exactly where they lie in relation to other harbor/coastline landmarks.

This map window also has a plot-type feature that allows the user to switch back and forth between temperature and conductivity plots. Simply changing the plot type from the drop- down list will update the map with the correct data. The color bar has a text field for setting the lower and upper limits of the color bar. For these setting to take effect, the user must change the limits to the values needed and then select the plot type from the plot type drop-down list. This change causes the software to recapture the entered limits and adjust the color bar and data map accordingly.

The Notepad section is useful for noting specific information about a certain data run, or data collection point. It is not required to be used; however, if it is, the data contained there will be written to a flat file when the program is closed.

Trident GUI Layout

The layout for the GUI is shown below:



Section 1 - The Control Buttons

Station ID Field: The Station ID field allows for a unique identifier to be associated with the acquisitioned data. The name in this field is used as the first part of the filename of the acquisitioned data. Please use "_" (underscores) instead of spaces. The full filename consists of the string from this field and a date/time stamp. The default extension for these data files is ".raw". Since this field is required, data capturing cannot occur until this field is populated; however, since the date/time stamp for each file is unique, no error checking is done to ensure that this field is changed between point acquisitions.

Activate Probes: The Activate Fields button is a toggle button, and thus has two states, on and off. Upon the first pressing of this button, the COM ports are assigned to each of the measuring devices: the GPS receiver, the Temperature probe, and the Conductivity probe. Subsequent activations do no reassign the COM ports. The GPS receiver is queried once and the Latitude/Longitude fields (as described in Section 2 below) are updated to reflect the current position. The Temperature and Conductivity probes are then queried at a frequency of 1 Hz for as long as this button is activated. The data read from the probes are plotted continuously and in real time in their respective axes in the lower right corner of the GUI. The Temperature and Conductivity fields (as described in Section 3 below) are updated to reflect the current probe readings. This button can be deactivated in two different ways: by clicking the button to the off position, or by clicking the Capture Data button.

Capture Data: This button is only enabled when the probes are active, i.e., when the "Activate Probes" button is on. As soon as the data capture begins, the button is again disabled, the temperature/conductivity plots and the counter timer are reset to empty plots and 00:00, respectively. The functionality of this button is identical to the Activate Probes button, except for the COM port assignments. In addition, the data from the probes are written to a .raw data file for later analysis. The timer to the right of the Stop button displays the length of time the data have been captured. Data are captured until the Stop button is pressed.

Stop: The Stop button is only enabled after the Capture Data button has been pressed and is immediately disabled after being pressed. After this button has been pressed, the mean temperature and conductivity are calculated for the current data set, and depending upon what data plot type is specified (as described in Section 2 below), the mean is plotted as a point on the map with colored shading that dictates the value at that point.

Section 2 - Data and Map Functions/Features

Zoom: This button toggles the zoom feature on or off. When on, the user may either click on the map to zoom in on a specific point, or may click and drag the mouse to select an area on which to zoom. Right-clicking the mouse will zoom out. Clicking the zoom button again will turn the zoom feature off and freeze the map at the current level.

Current Location: The current latitude/longitude displays in decimal degrees. This field is only updated once per probe activation or data capturing, so the GPS receiver does not need to be held in place above the deployed Trident probe once the position is captured. Once the temperature and conductivity plots show data plotted, the GPS receiver may be moved.

Data Plot Type: This drop-down list gives the option for what data is to be plotted in the data map. If Temperature is selected, any collected temperature data are plotted and after capturing data is complete, the newly collected temperature data are also plotted. The converse is true when Conductivity is selected. Because the map is updated after a capture cycle is complete, this feature is temporarily disabled during data capturing.

Map: The data plot consists of color-shaded points that represent either the temperature or conductivity at specific coordinates on the map. The data displayed are determined by the selection in the data plot type field.

Color Scale and Limits: The lower limit field specifies the lower limit of the color band and the upper limit specifies the upper limit of the color band. The color band is not updated until either a data capture is performed or an option in the data plot type is selected or re-selected.

Section 3 - Temperature and Conductivity Data/Plots

Probe Data: As the probes are queried, whether in activation mode or data-capturing mode, these fields display the last value read from the probes.

Plots: As the probes are queried in activation or data capturing mode, these plots track the changes. The time axis always starts and stays at zero, so the points are "packed" in from the right. These plots are reset (erased) each time the probes are activated or a data capture is performed.

Trident Supplemental Information

The temperature probe returns the temperature in degrees Celsius.

The conductivity probe returns the conductivity in milliSiemens.

The porewater probe allows for the extraction of water (for sampling) while the probe is deployed.

The air hammer acts like a jackhammer in that it assists the probe to be inserted further into the sediment.

GPS Receiver

The GPS receiver uses the following:

- Port COM4 – Currently has a splitter to share the GPS data w/ another COM port (e.g. COM7) that would be read by another mapping software program (e.g., ChartView™).
- The black, 9-pin serial cable with the red velcro strap.
- The 9-pin serial splitter was created for use with the receiver so that the to National Marine Electronics Association (NMEA) output can be used simultaneously in MATLAB® for the Trident program and ChartView™, which currently contains the full map of survey area. (optional).
- Four AA batteries.

The GPS receiver generates the following serial output according to NMEA standards. The only lines used by the Trident GUI are marked in red as follows:

$GPRMC,POS_UTC,POS_STAT,LAT,LAT_REF,LON,LON_REF,SPD,HDG,DATE,MAG_VAR,MAG_REF*CC<CR><LF>

POS_UTC - UTC of position. Hours, minutes and seconds [fraction (opt.)].
(hhmmss[.fff])
POS_STAT - Position status. (A = Data valid, V = Data invalid)
LAT - Latitude (llll.ll) (ddmm.mm - whole degrees and decimal minutes)
LAT_REF - Latitude direction. (N = North, S = South)
LON - Longitude (yyyyy.yy) (dddmm.mm - whole degrees and decimal minutes)
LON_REF - Longitude direction (E = East, W = West)
SPD - Speed over ground. (knots) (x.x)
HDG - Heading/track made good (degrees True) (x.x)
DATE - Date (ddmmyy)
MAG_VAR - Magnetic variation (degrees) (x.x)

```
MAG_REF - Magnetic variation (E = East, W = West)
FIX_MODE - Position Fix Mode ( 0 = Invalid, >0 = Valid)
SAT_USED - Number Satellites used in solution
HDOP   - Horizontal Dilution of Precision
ALT   - Antenna Altitude
ALT_UNIT - Altitude Units (Meters/Feet)
GEO   - Geoid/Elipsoid separation
G_UNIT  - Geoid units (M/F)
D_AGE  - Age of last DGPS Fix
D_REF  - Reference ID of DGPS station
CC    - Checksum (optional)
<CR><LF> - Sentence terminator (carriage return and line feed)
```

The tags used by the Trident GUI are in bold above. For accurate data plotting, any coordinates in the southern or western hemispheres are stored as negative numbers; however, are displayed as positive numbers since the GUI specifies the direction.

Temperature Probe

The Temperature probe uses the following:

- Port COM5
- A heavy black cable with a round, 4-pin connector (the four pins form a square) on one end connected to a 25-pin to 9-pin gray serial cable on the other end. A 9-V battery to power the SBE temperature probe is connected via a red/black twisted-pair of wires attached to the gray 25-pin to 9-pin converter.
- The serial output from the temperature probe is in decimal degrees Celsius (format: cc.cccc).

Conductivity Probe

The Conductivity probe uses the following:

- Port COM6
- A gray serial cable with 9-pin connectors on each end.
- The GeoProbe® FC4000 field computer.
- Power supplied by the field computer (110v).

To get the FC4000 field computer into the correct mode to transmit data via the serial port, turn the unit on and select the following menu options:

1 - Conductivity
1 - For SC400
2 - To bypass all tests (if this is indeed the user's wish)
1 - For 1m rods
1 - For Wenner type conductivity probe

The serial output from the conductivity probe is in decimal milliSiemens; however, since the decimal is not transmitted with the data, the number is divided by 100 to get the actual decimal. (serial format: cccccc, program format: cccc.cc)

Appendix C: Checklist For UltraSeep

Prep and Sampling				
• Log Book				
• Manuals (ESM-1, MiniLogger, Pump, Valve)				
• Ct Chargetek 500 Battery Charger				
• Cleaning Solutions				
• Extension Tubing For Sample Line From Funnel				
• Sample Bags (Alltech # 41012)				
UltraSeep				
• Meter (with Charged Battery)				
• Lift Bridle				
• Wheels and Pins				
• Cover for MiniLogger Display				
• MinLogger Display Cover in Place				
• Dummy Plug for MiniLogger RS-232 BC Connector				
• Misc Dummy Plugs				
Computer and Cables				
• Computer(S), UltraSeep Programs, Power Cords				
• ESM-1 Power/Com Interface Box				
• 100’ ESM-1 Com Cable				
• 100’ Cable for MiniLogger with Dummies				
• RS-232 Adaptor Cable with DB-9				
• External Switch for Pump to Put into Ext RS-232				
• 2 X 12-V Small Batteries to Power Solenoid Valve				
• GPS				
Deployment/Retrieval				
• Primer Bulb				
• Marker Buoy				
• Tie Wraps				
• Lift Bags				
• Ice Chest for Samples				

APPENDIX D: UltraSeep Pre-Deployment Checklist

Refer to “Checklist For UltraSeep” for Necessary Items				
Battery Charged (Check Voltage?)				
Pump Tubing Loaded in Pump Head				
Intake Sample Line Attached at Funnel				
Sample Lines Attached to Bags				
Valve Stems on Bags Open (Pulled Out)				
Pouches Zip-Tied to Top to Retain Bags				
MiniLogger Programmed				
ESM-1 Programmed with Proper Delay and Valve Periods				
Start and Sample Sequence Start/End Noted in Log				
Release Shackle Attached to Bridle				
Wheels Removed				
Remove Air Bubbles Trapped in Funnel				
Prime Flow Tube				
Use Caution Not to Get New Air Bubbles Inside Funnel				
Zero Flow Tube				
Connectors/Cables Dummy Plugged				

APPENDIX E: UltraSeep Cleaning Procedures

CLEANING SCHEDULE (per line)

- 4 minutes detergent (2% Alchonox® or RBS)
- 2 minutes 10% acid (if necessary)
- 2 minutes 18 mega-ohm deionized (DI) water

1) Prepare cleaning solutions in carbuoys:
   a. 10 liters of 18 mega-ohm deionized water
   b. 5 liters of warm 2% RBS or Alconox®, depending on analysis
   c. 1.5 liters of 10% nitric acid if analyzing metals

2) Attach the extension tubing to the detached sample line from the funnel. Place this line in the detergent container. Place a cup under each sample on the UltraSeep as fluids will drip from lines.

3) Make sure tubing is loaded in the UltraSeep's peristaltic pump head. Power-up UltraSeep and connect computer to ESM-1 using interface box as described in "Communicating with Meter." Select "Shortcut to ESM" and upload "Clean4.esm" (see Appendix E).

4) Start "Clean4" and inspect lines to make sure fluid is flowing. If there are flow problems, try raising the container to reduce the head.

5) Have the acid and DI containers together for the next portion of the cleaning process as the intake line from the acid container will be switched halfway through the 4-minute cycle to the DI container for each sample line. The use of a stopwatch is recommended.

6) Load the Teflon® sample bags into the mesh pouches with the valve stems pointing inward, through the mesh, and push onto sample tubing. Pushing the valve stem onto the tubing will close the valve stem. **It is necessary to pull the valve stem out to collect samples.**

APPENDIX F: MiniLogger Set-Up

Note: The following should be done before programming the ESM-1

Select Shortcut to "Flowm" from computer desktop				
Connect MiniLogger com cable and RS-232 cable to computer RS-232				
Hit Enter to get prompt (takes a while or hit again)				
Type in "menu" (repeat typing in "menu" if you do not get it the first time)				
Go to METER FACILITIES (right arrow to select)				
Scroll to datalogger control (use up/down arrows then right arrow)				
Select "CLEAR DATALOGGER" > YES				
Go back to main menu (use left arrow)				
Select 2 CHANNEL FLOW using right arrow				
Select CHANNEL 1 FLOW TUBE				
Select Datalogger setup				
Select Datalogger mode				
Select "Yes" for MEMORY				
Once deployed, zero meter and save value as new zero value				

APPENDIX G: ESM-1 Programming Highlights

Two programs are used for the programming of the ESM-1 controller/logger. A context editor is needed to write/change the programming scripts for the ESM-1; we use ConText Editor. The other program is Hyperlink, which communicates with the ESM-1.

The following are major areas for attention (also see following page):

Context Editor

Edit "Main" File:

- Check the number of "repeats" for the startup delay and change to anticipate delay from the time of downloading program to ESM-1 to the time it begins sampling. Each repeat = **5 minutes**, ex. 36 repeats = 3 hours (default).
- Change filename for new site in two places.

Main Loop:

- Change the pump loop filename in 6 places at end of sub routine.

Edit "Pump" file:

- Outside repeat is the time between switching valves. One repeat = **10 minutes**, ex. 15 repeats = 2 ½ hours. Change, if necessary.
- Change filename for new site.

ESM-1 Uploads

- Connect ESM interface box to computer and ESM
- "Shortcut to ESM", hit enter, wait for prompt, and type in "cd /store/eep/micro" to go to program area of ESM-1
- Type "dir" at new prompt to see list of programs on ESM
- Type "del 'filename'" to get rid of files if more memory needs to be cleared on the ESM for the new site (need 5000 bytes free for one tidal cycle at 5-minute sampling)
- Type "upload 'filename'" for pump file at prompt (name you want it to be called) and hit Enter. Should say "Ready to receive text"
- Go to Transfer menu, click "send text file"
- Select file to upload from C:\ESM (look at all file types) and open template file to upload to ESM-1. Inspect file while uploading to see if everything looks good.
- Hit Cntrl-C when done.
- Repeat from step "5" for uploading new "main" file.
- To run ESM, type in filename for "main" and hit enter.

EDITING ESM-1 PROGRAM FILES

The following is a portion of the "main" file for programming the ESM-1. Nine places require attention:

Legend:

repeat: used to delay water sampling sequence. Repeat = 5 minutes for "main" file, 10 minutes for "dump" file.

site name: change in eight places and "save as" new file.

```
#start up delay
repeat 36  #***
 transmit 1,"Startup delay\r\n"
 burst 1000,300,"Flow","/store/cf/pw3a",display #***
end

#now start doing something real
execute "/store/eep/micro/pw3apump" #***

digitalio 10,set
wait 10000
transmit 3,"go2\r"
wait 5000
digitalio 10,clear
transmit 1,"go2\r\n"
execute "/store/eep/micro/pw3apump" #***

digitalio 10,set
wait 10000
transmit 3,"go3\r"
wait 5000
digitalio 10,clear
transmit 1,"go3\r\n"
execute "/store/eep/micro/pw3apump" #***
```

The following is a portion of the “pump” file with areas of attention highlighted:

```
#start pump loop
repeat 15 #number of times to repeat sample burst for each valve ***
    burst 1000,300,"Flow","/store/cf/pw3a",display #***
    flow02=[Analog 2]
    if flow02 > 23300 #4V ***
      transmit 2,"bm%100\r" #***
      transmit 1,"bm%100\r"
      wait 100
      transmit 2,"bmr\r"
```

APPENDIX H: UltraSeep Data Downloading

Downloading data from the ESM-1

- Hook up com cables
- “Shortcut to ESM” and hit Enter to get prompt
- Type in “cd cf” to change the directory to Compact Flash (ESM-1 memory) to see if filename setup during programming is listed.
- Type “extract /store/cf/’filename’, synopsis, compact” but DO NOT HIT ENTER
- Go to “Transfer Menu”>”Capture Text”> rename if you want new name.
- Hit Start then Enter
- Go back to “Transfer” menu > “Capture Text” > Stop

Downloading data from MiniLogger

- FLOWM shortcut
- Type “logger” at prompt, but DO NOT HIT RETURN
- Go to “Transfer” > “Capture Text” > type in filename for site
- Click “Start” > Enter
- When data stream has stopped, go back to “Transfer Menu” > “Capture Data” > “Stop”

“Open Pipe”

- Run ESM Shortcut
- Type “cd eep/micro” at prompt <enter>
- Type “initserial 3,9600” to initalize port 3 (valve port on ESM) <enter>
- Type “digitalio10, set” to turn on converter (“digitalio10,clear” to turn off converter) <enter>
- Type “openpipe3” <enter>
- Type “go_”, use 1 through 6 in the blank to advance valve to position <enter>
- Type “cp” to ask where the valve position is presently located <enter>

APPENDIX I: ESM-1 DATA PLOTTING

Quick Check

In Microsoft® Excel, column A is flow, B is pressure (depth), and C is temperature.

- Open Microsoft® Excel
- Open file (look/find file in ESM folder where file is stored); it should appear as "(site name)**syn_compact.dat**"
- Use "delimited" and "comma" when dialog box opens
- Highlight the particular column you want to graph (a, b, or c)
- Go to View > Insert Menu > Line graph

Data Processing:

- Open the appropriate "…..syn_compact.xls" and the "Seep meter Template.xls" files.
- Copy only the data values of A, B, and C columns of "….syn_compact.xls" file into the "raw data" sheet of the template file. Instructions are on the "raw data" sheet of the template and are as follows:

NOTES

1. Delete old data from yellow box (do not delete time column)
2. Paste new raw data (numbers only) into yellow box (from ESM syn_compact.xls file)—use "paste as values" (clipboard icon with "12")
3. Enter new start date/time in blue box (date/time for beginning of ESM file)
4. Enter in the row number for start time of sample #1 in the red box above
5. Make sure autofilter is turned off in Parse Data sheet
6. Delete old data from Parse Data sheet
7. Copy data from Raw Data sheet (including date/time)
8. Line up the first row of raw data at the line specified in red box above in the Parse Data sheet
9. Paste as values on the Parse Data sheet (clipboard icon with 12)
10. Put cursor at top of column one and autofilter data on Parse sheet for column one using a filter of 1 (use blue arrow at top of column one)
11. Delete raw data in purple box on the Formatted Data sheet
12.Copy the filtered data including time from the Parse data sheet (not including pump status)
13. Paste as values on the Formatted Data sheet (clipboard icon with 12)
14. Adjust plot ranges in plot sheets to match the length of the data in the Formatted Data sheet (in command line {fx})
15. Save the file under a new name that corresponds to the deployment name (Save As)

APPENDIX J: MiniLogger Data Plotting

1. Import data file from logger in into Microsoft® Excel worksheet
2. Determine deployment start time-remove first 2 hours of data (adjustment period after deployment)
3. Check error codes, signal strength, and sound velocity (V_s) in output file to assure proper operation of meter
4. Use average flow data to convert flow rate to specific discharge as follows:
    a. Convert average flow rate to velocity by accounting for area of flow tube (area of flow tube = 0.7129 cm2)
    b. Relate this velocity to velocity in funnel (ratio of funnel to flow tube is 0.0003411 for funnel area of 2090 cm2
    c. Convert from cm/sec to cm/day by multiplying by 86400 sec/day
    d. Optional—convert to rate by adjusting for area of discharge for given time
5. Plot data—data usually plotted with tide